Journal of Risk Research **4** (4), 309–322 (2001)

A Communication–Human Information Processing (C–HIP) approach to warning effectiveness in the workplace

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Abstract

Warnings are one of several hazard control methods used to protect employees and property against danger and loss. This article surveys a set of factors known to influence the effectiveness of workplace warnings. The description of empirical research is organized around a communication–human information processing (C–HIP) model. The model begins with a source entity attempting to relay a warning message through one or more media/sensory channels to one or more receivers. At the receiver, processing begins when attention is switched to the warning message and then maintained while information is extracted. Processing continues through the successive stages of comprehension, beliefs and attitudes, motivation, and ends with compliance behaviour. Any of these stages can be a bottleneck that causes processing to stop, diminishing the effectiveness of the warning. The factors that are influential at each stage are described. The C–HIP model provides a structure to systematically examine factors that can cause risk communication to fail and for finding ways to improve risk communication in the workplace.

KEY WORDS: warnings; safety; hazard control; risk perception; human information processing

1. Introduction

Warnings in the workplace have three main purposes. First and foremost, they are a vehicle for communicating important safety or safety-related information to a target audience of employees, and in some cases, visitors. Second, they attempt to promote safe behaviour and reduce unsafe behaviour. For example, warnings might direct or remind people to use personal protective equipment such as safety glasses and hard hats. Third, warnings are ultimately intended to reduce or prevent health problems, workplace accidents, personal injury, and property damage.

Workplaces vary tremendously depending on the nature of the work being performed – from athletic fields to doctor's offices to airplane cockpits. In this article, examples are focused on industrial workplace settings where hard goods are manufactured and distributed. Nevertheless, the concepts discussed are pertinent to most types of workplaces.

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Journal of Risk Research
ISSN 1366-9877 print/ISSN 1466–4461 online © 2001 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/1366987011006271 2

Just as there are many kinds of workplaces, there are also many kinds of warnings. They can be in the form of signs, labels, product inserts and manuals, lock out tags, audio and video tapes, admonishments from co-workers and supervisors, handouts distributed at safety training meetings, auditory alarms, and so forth. Printed warnings are generally text and graphics. Auditory warnings may be both verbal and nonverbal. In this article workplace warnings are defined as formal communications from some authority person or organization directed toward individuals (employees, visitors, etc.) in a work environment for the purpose of providing information, promoting safe behaviour and preventing injuries and property damage. These communications are typically auditory or visual in nature and pertain to hazards that are constantly or repeatedly present in the workplace. While the model described is generally applicable to all types of warnings, most of the examples presented in this article are orientated toward warnings found on posted signs and product labels that might be encountered in a work environment.

While the topic of this article concerns occupational-related warnings, it is readily admited that warnings are not the best method of controlling hazards and promoting safety. Even the best warnings are not always reliable or 100% effective. The best method of hazard control is to eliminate (or remove) the risk from the workplace. If the risk is not present then the likelihood of injury is greatly reduced. For example, redesigning a dangerous material handling process by having machines, instead of humans, transport hazardous materials, reduces workers' exposure to the hazard, making it much less likely that they will be injured. Similarly, a programmed robot might replace human operators in injury-prone occupations like operating a punch press. Or it may be possible to remove a dangerous chemical from the workplace by substituting a safer chemical. The substitution eliminates or reduces the hazard (e.g., breathing dangerous vapours) and consequently employees' risk of injury. Of course before any change is actually implemented there needs to be some forethought about how the change might impact the entire system or process so that no new hazards are created in designing out the original hazard.

Unfortunately, hazards cannot always be eliminated. For example, it is not possible to eliminate all of the hazards associated with chemical solvents if the company manufactures solvents. Likewise, it is not possible to remove all of the mechanical hazards related to power tools from an operation that produces wooden furniture. For hazards that cannot be eliminated, the next best hazard control strategy is to guard against contact with the hazard by people and property. Wearing protective equipment such as a full-face respirator with an independent air supply separates an employee from hazardous solvent vapours. Similarly, a plexiglass shield placed around a high-speed lathe guards workers in a furniture factory from flying debris.

Unfortunately, not all workplace hazards can be removed or guarded against. In such cases warnings are necessary. As already stated, warnings are not the best method of hazard control because they do not always accomplish their intended effects. Thus, an important issue for safety is how to design warning systems to maximize their effectiveness. One purpose of this article is to describe some of the factors that affect (increase and decrease) warning effectiveness.

Field experimentation on warnings in actual occupational settings is rather limited. Researchers cannot ethically expose employees to real risks for the sake of designing a good experiment in which warning designs are manipulated. Doing so might put workers exposed to weaker manipulations at undue risk. One exception is using a pre-

and post-intervention design where in the existing condition no warning or a poor warning is present and it is replaced by a better warning (Wogalter and Dingus, 1999). Because of the difficulties associated with field studies most warning compliance research is conducted in the laboratory using simulated risk situations where no real risk exists. Or, if an actual risk is present the procedure is stopped before the participant comes into contact with a hazard (Wogalter and Dingus, 1999). It is often difficult to create realistically appearing risk situations in the laboratory, so instead of measuring behavioural compliance, researchers often take measurements at intermediate stages of warning processing that are precursors to behavioural compliance. The idea is to gain insights into the benefits of warning-related factors using nonbehavioural measures such as questionnaires that assess people's beliefs and attitudes. Research in social psychology (Kim and Hunter, 1993; Kraus, 1995) has established a causal link between attitudes and behaviour. Dejoy (1999) uses a value-expectancy framework to show that beliefs and attitudes can influence behavioural compliance with warnings by altering warning recipients' expectations about possible consequences.

A starting point for warning designs are current standards and guidelines such as those put forth by the American National Standards Institute's Z535 document (ANSI, 1998). According to these guidelines warnings should posses four textual components: (1) a signal word such as DANGER, WARNING or CAUTION to attract attention to the warning and give an idea of the potential level of hazard, (2) a hazard statement which briefly describes the nature of the hazard, (3) a description of the possible consequences associated with noncompliance, and (4) instructions for how to avoid the hazard. In addition, a pictorial symbol depicting the hazard, consequences, or appropriate or inappropriate behaviours is also recommended. Research has verified the importance of the above-mentioned components for enhancing warning efficacy (Wogalter *et al*., 1987; Young *et al*., 1995). Not all of the components are necessary if virtually all members of the target audience know all of the information in the warning. However, while a warning with already-known information can appear to have little or no utility, its presence might serve as a reminder that cues pre-existing knowledge about a potential hazard from long-term memory into awareness (e.g., Young and Wogalter, 1990).

The remainder of this paper is based on a conceptual model that combines basic components of communication and human information processing theory. While considering the stages, examples of issues and factors pertaining to workplace warnings will be described.

2. The Communication–Human Information Processing (C–HIP) Model

The Communications–Human Information Processing (C–HIP) model (Wogalter *et al.*, 1999b) is a framework for structuring the stages involved as information flows from a source to a receiver who then processes the information to subsequently produce behaviour. Figure 1 shows a depiction of the model. This model takes from communication theory (Lasswell, 1948; Shannon and Weaver, 1949), the conceptual stages of Source, Channel, and Receiver. (For simplicity the model excludes other parts of communication theory such as 'noise.') The Receiver stage is broken down further into several human information processing substages: Attention Switch and Maintenance, Comprehension, Beliefs and Attitudes, and Motivation to carry out the compliance Behaviour. Each of these stages will be discussed in turn.

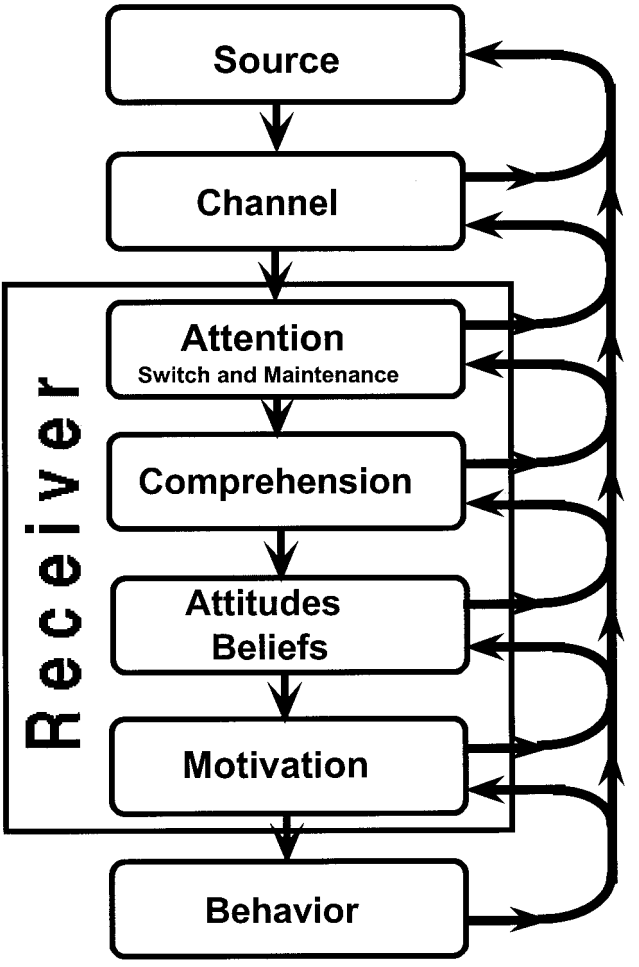

Fig. 1. Communication–Human Information Processing (C–HIP) model

Each stage of the model can allow information to 'flow through' to the next stage, or it can produce a bottleneck which blocks the flow before the process ends in behavioural compliance. While warning information might not lead to behavioural compliance, it still might effectively influence precursor processing stages. For example, information can positively influence comprehension yet not produce an effect on beliefs and attitudes or affect motivation or change behaviour. Such a warning cannot be said to be totally 'ineffective' as it does produce better understanding. However, it is ineffective in the sense that it does not produce safe behaviour by some people.

Accordingly, the model predicts that if a source does not issue a warning, the message cannot be transmitted. No information will be transmitted to the channel stage and thus nothing will be communicated to the receiver. Even if a warning is issued by a source, it will not be effective if the medium of transmission is poorly matched with the message, the receiver, or the environment. Each of the receiver's information processing stages can also produce a bottleneck preventing further processing.

The receiver might not notice the warning. They might not stop and direct their attention to the warning. They might not understand the warning. They might not believe the warning's message. Or, they might not be motivated (or energized) to take action.

Although the processing described above is linear, there are feedback loops from later stages to earlier stages as illustrated in Fig. 1. An example is that when a warning stimulus becomes habituated over time from repeated exposures, attention is less likely to be allocated to the warning on subsequent occasions. Here, memory (as part of the comprehension stage) affects an earlier stage of processing, attention. Another example is that some people might not believe the content of a warning or believe that a product or situation is hazardous. As a consequence they might not look for a warning, or if they do, they might not maintain attention to it. These feedback or nonlinear effects among the stages of the information processing model provide a means by which later stages influence decisions at earlier stages.

In the sections that follow, each of the stages of the C–HIP model is described together with corresponding influential factors.

3. Source

The source is the originator or initial transmitter of the risk information. The source can be a person(s) or an organized entity (e.g., the company or the government). Before the source actually transmits a warning there must be a recognized need for the warning. Research shows that given the same information, differences in the perceived characteristics of the source can influence people's beliefs about the relevance of the warning (Wogalter *et al.*, 1999b). Information from a positive, familiar, credible, expert source is given greater attention, which in turn facilitates understanding and possibly leads to changes in beliefs and attitudes about the information presented. It would be expected that a public service organization whose prime focus is safety (e.g., the Health & Safety Executive [HSE] or the Occupational Safety & Health Administration [OSHA]) is more likely to publish accurate, truthful materials including warnings about real hazards. Warnings attributed to these organizations, therefore, are likely to be perceived as more credible. Research (Wogalter *et al.*, 1999c) indicates that government agencies that have a good reputation can influence beliefs in favour of the message that they present.

4. Channel

The channel concerns the way information is transmitted from the source to one or more receivers. There are two basic dimensions of the channel. One concerns the media in which the information is embedded. Warnings can be presented on posters, in brochures, on product labels, as part of audiovideo presentations, given orally, etc. The other dimension of the channel is the sensory modality used by the receiver to capture the information. This dimension is intimately tied to the media in which the message is transmitted. Most commonly, warnings are received via the visual (printed text warnings and pictorial symbols) and auditory (alarm tones, live voice and voice recordings) modalities. There are exceptions: an odour added to very flammable gases like propane makes use of the olfactory sense, and a pilot's control stick that is designed to vibrate when the aircraft begins to stall makes use of the tactile and kinesthetic senses.

Until recently almost all of the auditory warnings emitted by machines were nonverbal, e.g., beeps, bells, horns (Sanders and McCormick, 1993; Edworthy and Adams, 1996). Sometimes the reason for an auditory alarm is obvious, but other times it may not be, and so may require some training to enable identification. However through the use of recent signal digitization technology, auditory stimuli can now be more complex, such as voice (verbal) presentations. Voice warnings make use of people's existing knowledge to identify the message's meaning. For example, a verbal message that states 'Fire!' multiple times clearly communicates the nature of the hazard. No interpretation is required, as might be with nonverbal auditory presentations.

One of the main advantages of presenting information through the auditory channel is that people's hearing is 'always on,' meaning that (except in cases of hearing impairment or the presence of higher intensity background noise), it is generally guaranteed that the message will impinge on the receptors in the ear. The auditory channel is useful when the visual modality may be occupied by another task. Combined print and voice warnings have been shown to be more effective than either alone (e.g., Conzola and Wogalter, 1999). The problem with auditory messages in the workplace is that concurrent sounds that are similar to and louder than the warning message (such as public address announcements or operating machinery) can negatively affect intelligibility (Sanders and McCormick, 1993). In such cases, a distinctive voice should be used that appears to emanate from a different direction than other sounds. Complicated, long-duration verbal messages can overload working (conscious) memory and are better conveyed visually. Visual presentation usually allows receivers to review a message if it was not attended to or comprehended initially, while auditory information may not be available for review.

5. Receiver

The receiver's mental activities can be categorized into a sequence of information processing stages. For a warning to effectively communicate information and influence behaviour, it must first cause attention to be switched to it and then attention needs to be maintained long enough for the receiver to extract the necessary information from the warning. Next, the warning must be understood, and must concur with the receiver's existing attitudes and beliefs. If it is in disagreement, the warning must be adequately persuasive to evoke an attitude change toward agreement. Finally, the warning should motivate the receiver to perform proper compliance behaviour. The next several sections are organized around the stages of information processing that occur within the receiver. Each stage is described, first as it relates to warnings in general, and then as it applies to warnings in the workplace.

5.1. ATTENTION SWITCH

The first stage in the human information processing section of the C–HIP model concerns the switch of attention. An effective warning must initially attract attention. Generally this must occur in environments which also have other stimuli competing for attention. Since many industrial environments are cluttered, visual warnings must stand out from the background (i.e., be salient or conspicuous) in order to be noticed. This is particularly true when people are not actively seeking hazard and warning informa-

tion. In the workplace most people are focused on the tasks they are trying to accomplish, and while safety considerations may be part of their background knowledge (stored in long-term memory), task completion (and not warning and hazard information) is most likely the focus of their attention.

One way by which a visual warning can be made more salient is increasing the print size and the print's contrast against the background (Barlow and Wogalter, 1993). Signal words and pictorials also tend to attract attention. In the US, current standards and guidelines such as those put forth by the American National Standards Institute's Z535 document (ANSI, 1998) recommend that warning signs and labels for hazards contain a signal word panel that includes the terms DANGER, WARNING or CAUTION along with a specific colour (red, orange, and yellow, respectively) and an alert symbol (a triangle surrounding an exclamation point). According to ANSI, these terms are intended to denote decreasing levels of hazard, respectively. DANGER should be used for hazards where serious injury or death will occur if the warning compliance behaviour is not followed such as around high voltage electrical circuits. WARNING is to be used when serious injury might occur, such as severe chemical burns or exposure to highly flammable gases. CAUTION is to be used when less severe personal injuries or damage to equipment might occur, such as getting hands caught in operating equipment. Research shows that lay persons often fail to differentiate between the latter two terms, although both are interpreted as being lower in connoted hazard than DANGER (Wogalter and Silver, 1995). Additionally, research has shown that pictorials are useful in capturing attention (Laughery *et al.*, 1993b; Bzostek and Wogalter 1999).

The placement of a warning in the visual space is also very important. For example, warnings directing the use of personal protective equipment should be displayed prominently on or near each entrance to a restricted area. In areas that are large or dispersed (like many factory floors), visual warning signs might not be the most effective way to communicate the necessary information. In such environments, auditory warnings (alarms and announcements) are an alternative means for alerting workers to the presence of hazards. Conversely, in environments that are extremely loud or where hearing protection is required, visual warnings (e.g., flashing lights on top of moving fork lift trucks) may be the best way to attract attention.

Unfortunately, repeated and long-term exposure to a warning may result in a loss of attention capturing ability (Wogalter and Laughery, 1996). This habituation can occur over time, even with well designed warnings. Altering a warning's appearance by periodically changing its format or content can slow the habituation process. Some companies post safety placards which are changed every so often to keep them 'fresh.'

5.2. ATTENTION MAINTENANCE

Individuals might notice the presence of a warning but not stop to examine it. A warning that is noticed but fails to maintain attention long enough for its content to be encoded is of little value. For further processing of warning information to occur, attention must be maintained on the warning's message (Wogalter and Leonard, 1999). With brief warnings the message information might be acquired very quickly (sometimes as fast as a glance). For longer warnings to maintain attention, they need to have qualities that generate interest, and do not require much effort. If a warning contains large amounts of text, individuals may decide that too much effort is required to read it, and

they turn their attention to something else. Some of the same design features that facilitate the switch of attention also help to maintain attention (Barlow and Wogalter, 1991; Wogalter *et al*., 1993b). For example, large print not only attracts attention, but also increases legibility, thus making reading less effortful and more likely.

Another factor that can influence attention maintenance is formatting. Visual warnings that are formatted to be aesthetically pleasing, with plenty of white space and coherent information groupings (Hartley, 1994), are more likely to attract and hold attention than warnings without these features (Vigilante and Wogalter, 1998). In general, bulleted lists are preferred to paragraphs of text (Desaulniers, 1987; Wogalter and Post, 1987). Full justification (the straight alignment of the beginning and ending words in at both margins), while aesthetically pleasing at a distance, is more difficult to read than 'ragged right' (justification of only the left margin) where the spacing between letters and words is consistent. Interest is also facilitated by the presence of well-designed pictorial symbols. In addition, research indicates people prefer warnings that have a pictorial symbol to warnings without one (Kalsher *et al.*, 1996; Young et al., 1995).

Even though placement of warnings directly on a hazardous product is preferred (Wogalter *et al.*, 1987), the available surface area on which to print warnings is sometimes an issue. Detached (physically separate from the product) documentation such as product manuals provide more space to print warning information. However, product manuals may be stored at a different location from the product (e.g., filed in a location remote from the hazard or thrown away). It is therefore advisable to keep a copy of all manuals with (or close to) the product while the originals are kept on file. Since generally safe equipment can become dangerous if not properly maintained and repaired, a copy of the maintenance and repair manual should be accessible.

5.3. COMPREHENSION

A warning that is attended to and examined has little value if the recipient does not understand its message. A warning message should give the receiver an appreciation of risks and enable informed judgment. For this reason, warnings should state their messages as explicitly as possible (Laughery *et al.*, 1993a). For example, a warning for an industrial solvent that says, 'Use only under an exhaust hood with a fan capable of moving 5000 cubic feet of air per minute' conveys more meaning than the statement 'Use with adequate ventilation.' The latter statement is vague and can be interpreted to mean something very different than what was intended by the solvent manufacturer. Whether a warning will be understood depends on characteristics of both the warning and the receiver. To maximize comprehension, warnings should be written considering the lowest-level abilities in the target population. For warnings targeted to the general population, one cannot assume that every person who receives the warning can read or has been formally educated. For situations where this is a concern, complex messages might need to be re-written using simple, frequently encountered terms which may involve adding explicit explanations. At the same time, the message should be as concise as possible (while still communicating all of the pertinent information). Thus there is a tradeoff between brevity and completeness. Readability indices, which are supposed to 'automatically' assess the grade level or percentage of the population that will understand text, can be useful but can also be misleading (Klare, 1976), so they should only be used as a starting point in determining readability.

Increasingly, multinational companies are hiring highly diverse work forces. In addition, products are shipped throughout the world. To reach all members of the target audience, it might be necessary to present warning information in multiple languages or to use understandable pictorial symbols. Pictorial symbols can be used to complement warning text, or when a pictorial symbol is readily recognized and understood, it can be used without text. In many industrial settings, the pictorial symbols used to identify the need for safety glasses and hard hats are so well understood they are rarely accompanied by text. Safety knowledge may also benefit from the incorporation of visual demonstrations such as multimedia training presentations and periodic safety meetings where warnings and safety directives can be reinforced.

Whether warnings are presented by language or by symbol they should always be tested with representative members of the target audience before being put into use. Wogalter *et al*. (1999a) provide a methodology for iteratively testing warnings to ensure their comprehension. Not only will testing identify warnings that are difficult to understand, but it will also identify those whose meaning could to be misinterpreted. Misinterpretation (critical confusion) can be a more serious problem than simply a lack of comprehension. A warning that is not understood might simply be dropped from further cognitive consideration, but a warning whose meaning is misinterpreted could suggest hazardous behaviours. For example, most workers do not realize that a rating of '3' in the National Fire Protection Code for chemicals is classified as being extremely hazardous with respect to the categories of health effects, toxicity, flammability, and oxidation (Lehto, 1998). People unfamiliar with the scale used can easily misinterpret a rating of '3' to be a relatively low level of risk and behave inappropriately.

5.4. BELIEFS AND ATTITUDES

If a warning successfully captures and maintains attention and is understood, then it still might fail to elicit safety behaviour due to discrepant beliefs and attitudes held by the receiver. Beliefs refer to an individual's knowledge of a topic that is accepted as true. Attitudes are similar to beliefs but have greater emotional involvement. According to the C–HIP model, a warning will be successfully processed at this stage if it concurs with the receiver's current beliefs and attitudes. The warning message will tend to reinforce what the receiver already knows (and in the process make those beliefs and attitudes stronger and more resistant to change). If, however, the warning information does not concur with the receiver's existing beliefs and attitudes, then in order to be effective a warning must change those beliefs and attitudes. In the next several paragraphs, how familiarity, hazard perceptions, perceived likelihood of injury, and perceived severity of injury relate to beliefs and attitudes is described.

In general, when people believe that they are familiar with a product, task, or environment, they are less likely to search for warnings (and thus are less likely to attend to them) or read them even if they see them (e.g., Godfrey *et al*., 1983; Wogalter *et al*., 1991). Familiarity beliefs are formed from past similar experience where at least some relevant information has been acquired and stored in memory. Familiarity produces the belief that everything that needs to be known about a product or situation is already known (Wogalter *et al*., 1991). This belief then leads to complacency and overconfidence and reduces the likelihood that a person will seek additional information. In most work settings, employees spend several hours each work day in the

same environment and have become extremely familiar with it. Such familiarity can be detrimental when new processes or equipment are introduced. A worker familiar with a certain piece of equipment might assume that a new, similar piece operates the same way (which may not be true) and thus might not attend to warning information and might perform unsafe behaviours.

Hazard perception also influences warning processing at the beliefs and attitudes stage. It is related to familiarity in that familiar products tend to be perceived as less hazardous. Persons who do not perceive a product as being hazardous are less likely to notice or read an associated warning (Wogalter *et al*., 1991; Wogalter *et al*., 1993a). And even if they do read the warning and know its content, they might not comply if they believe the level of hazard is low.

If warning information does not conform to, or is discrepant with existing beliefs and attitudes, then an effective warning must be sufficiently persuasive to change the person's beliefs and attitudes. While bringing about this change is not an easy task, it is facilitated if the information is presented in a form that will be noticed, read, and understood using the warning design characteristics discussed earlier. The message must be strong and persuasive enough to override pre-existing knowledge and experience. Wogalter *et al*. (1995) showed that an appropriately placed, interactive warning can be successful in overcoming people's familiarity beliefs and influence them to read and comply with warnings.

5.5. MOTIVATION

If a warning is noticed, read, understood, and concurs with a person's beliefs and attitudes (or is strong enough to change discrepant beliefs and attitudes), the process moves to the motivation stage. To be effective at this stage warnings must motivate the desired behaviour. An important factor influencing motivation is the balance between the cost of complying with a warning and the cost of noncompliance. When people perceive the cost of compliance to be greater than the benefits, they are less likely to perform the behaviour directed by the warning. The requirement to expend even a minimal amount of extra time or effort can reduce motivation to comply with a warning (Wogalter *et al*., 1987; 1989). One way of reducing the cost of compliance is to make the directed behaviour easier to perform. For example, if there is a part of an industrial facility where hearing protection is required, warning signs should be posted at each entrance demanding that the proper equipment be worn and instructing where to get the equipment. Earplugs or other hearing protection should be available near the signs so that minimal effort is required to comply. Comfort and proper fit are key factors in cost of compliance. If workers find protective equipment to be bothersome, they will be less likely to wear it (Casali and Epps, 1986).

The costs of noncompliance with a warning can also have a powerful influence on compliance motivation. Possible injuries associated with noncompliance should be explicitly stated in the warning (Laughery *et al*., 1993a). Explicit injury outcome statements such as 'Can cause liver disease – a condition that almost always leads to death' give reasons for complying and are preferred to general statements such as 'Can lead to serious illness.'

Another factor influencing motivation to comply is the safety culture of the organization or company. Generally, it would be expected that a warning would be more

likely to motivate compliance behaviour if employees believe that safety is an important part of their jobs. Some companies offer employee incentives and rewards for reducing workplace injuries and maintaining excellent safety records. Supervisors should make sure that all employees are familiar with company safety policies and the negative job consequences (costs of noncompliance) of failing to adhere to safety guidelines and warnings in their work. In addition to communicating policy, supervisors should set a proper example by modelling safe behaviour and warning compliance. Supervisors and experienced employees are role models to younger, less experienced workers and exert powerful social influences over them. If less experienced workers observe more experienced workers not complying with a warning to wear protective equipment, they may not believe safety is taken seriously and will be less likely to engage in compliance behaviour themselves (Wogalter *et al*., 1989).

Other factors that influence motivation to comply with a warning are time stress (Wogalter *et al*., 1998) and mental workload (Wogalter and Usher, 1999). In high stress and high workload situations, competing activities absorb some of the cognitive resources available for processing warning information and carrying out the compliance behaviour. In conditions such as these, considerable emphases on safety may be required to overcome the cognitive barriers.

5.6. BEHAVIOUR

If sufficiently motivated, then individuals will carry out the warning-directed behaviour. Behavioural compliance research shows that warnings can change behaviour (e.g., Laughery *et al*., 1994; Cox *et al*., 1997). See Silver and Braun (1999) for a concise review of published research that has measured compliance with warnings under various conditions.

6. Summary and discussion

In this article, some of the factors that can influence the processing of warning information have been reviewed. The review was organized around the C–HIP model that breaks the processing of warnings into separate stages that must be completed successfully for compliance behaviour to occur. A bottleneck at any given stage can prevent processing from occurring at subsequent stages. Also some simple examples of workplace hazard situations have been given in which some of the factors could play a role.

In summary, the model begins with a source (a person or some larger group entity) with knowledge of a hazard for which warning information must be conveyed to protect people from injury and property from damage. Source characteristics that exert positive influences include credibility, expertness, and likability. The source transmits the message through one or more channels to receivers' sensory systems. The receiver must then notice the information and switch attention to the warning as opposed to switching or maintaining attention to other potential stimuli in the environment. After attention is switched to the warning, the next stage is attention maintenance where attention must be held long enough for the warning's information content to be encoded and passed to the next stage of processing, comprehension. In the comprehension stage, the necessary risk knowledge to avoid injury and/or damage is activated in the mind of the receiver. Although the information in the warning may now be known, a bottleneck to

further processing is possible if the information is not consistent with the receiver's pre-existing beliefs and attitudes. If this is the case, then the warning must be strong enough to change the receiver's discrepant beliefs and attitudes. Even if the warning information passes through the beliefs and attitudes stage behaviour might still be unaffected if the warning does not adequately motivate the receiver to engage in the directed action. Compliance likelihood is enhanced when the directed behaviour is easy and comfortable to perform.

The basic C–HIP model can aid in determining why a warning does not work by identifying potential processing bottlenecks. Suppose that in an industrial setting it is observed that a critical warning sign is not working (as indicated by the fact that some people are not complying with it). The first reaction to solving the compliance problem might be to increase the size of the sign so more people are likely to see it. But noticing the sign (the attention switch stage) might not be the problem. Rather, user testing might show that workers report that they have all seen the sign (attention capture stage), and that they have read it (attention maintenance stage) and understood it (comprehension and memory stage), and that they believe the message (the beliefs and attitudes stage). The problem with the warning may actually be at the motivation stage – the workers are not complying because they believe the cost of complying with the warning (wearing ill-fitting and uncomfortable personal protection equipment, for example) outweighs the perceived slight probability of getting injured by not wearing the equipment.

By using the model as an investigative tool and testing a warning at different stages, one can determine the specific causes of a warning's failure and not waste resources trying to fix the wrong aspect of the warning design. To deal with the motivation stage blockage, the employer in the above example could make better fitting equipment available that can be adjusted in size to fit each individual. Or the writer of the warning could make the wording of the warning more persuasive by explicitly stating that the hazard accumulates over time and that it does not show its devastating effects until some 5 to 10 years later. Another persuasive message might be 'anyone found not wearing the equipment will be immediately terminated from the job.'

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